

Los Alamos National Laboratory Considers the Use of Biodiesel

A new EPA-approved alternative fuel, called biodiesel, may soon be used at Los Alamos National Laboratory in everything from diesel trucks to laboratory equipment. Biodiesel transforms vegetable oils into a renewable, cleaner energy source that can be used in any machinery that uses diesel fuel. For the past couple years, the Laboratory has been exploring the possibility of switching over to soybean-based biodiesel. This change could lead to many health and environmental benefits, as well as help reduce the nation's dependence on foreign oil.

What is Biodiesel?

Biodiesel is a clean, renewable diesel fuel substitute made from soybean and other vegetable oil crops, as well as from recycled cooking oils. A chemical process breaks down the vegetable oil into a usable form. Vegetable oil has a chain of about 18 carbons and ordinary diesel has about 12 or 13 carbons. The process breaks the carbon chains of the vegetable oil and separates out the glycerin (a fatty substance used in creams and soaps). The co-product of glycerin can be used by pharmaceutical and cosmetic companies, as well as many other markets. Once the chains are shortened and the glycerin is removed from the oil, the remaining liquid is similar to petroleum diesel fuel. It can be burned in pure form or in a blend of any proportion with petroleum diesel. To be considered an alternative fuel source by the EPA, the blend must be at least 20 percent biodiesel (B20). According to the U.S. Department of Energy (DOE), biodiesel is America's fastest growing alternative fuel.

Although the technology is new, the concept of biodiesel is quite old. Rudolph Diesel, the inventor of the engine that bears his name, said in a 1912 speech, "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in the course of time as important as petroleum and the coal tar." Nine decades later, his vision is finally being fulfilled with the growing support for biodiesel.

There is good reason for the growing use of biodiesel. The alternative fuel is biodegradable and non-toxic to plants, animals, and humans. This environmental benefit comes with little loss in production efficiency. The replacement of diesel with biodiesel is almost one to one. The U.S. Department of Agriculture (USDA) and the DOE performed a life-cycle analysis, which studied the biodiesel energy requirements from soybeans to fuel. According to this study, every gallon of biodiesel produced replaces 0.95 gallons of petroleum-based diesel. The ratio is not exactly one to one because the production of biodiesel requires a small amount of petroleum input. Examples of biodiesel petroleum input would be the use of fuel for tractors, bailers, or refinery equipment. For petroleum diesel, the fuel would be used in extraction and refinery equipment.

Another advantage to using biodiesel is that there is a gain in the amount of energy yielded from the original fossil energy. Biodiesel requires only 0.31 Btus of fossil energy to make 1 unit of liquid fuel capable of producing one Btu (one liquid Btu). By contrast, it takes 1.2 Btus of fossil energy to produce 1 Btu of petroleum diesel. In other words, petroleum diesel requires about four times the amount of fossil energy input as biodiesel. This can be explained by the fact that

biomass is substituting for the proportion of fossil product that makes up all diesel fuel. Even though there is some fossil energy used in biodiesel production, there is a more efficient use of the petroleum than in standard diesel production. This concept can also be looked at in terms of the energy yield of a fuel. For every Btu of fossil fuel energy used to produce biodiesel, 3.2 liquid Btus of energy are gained, or yielded. The energy yield of biodiesel is 285 percent greater than petroleum diesel fuel. Comparisons of biodiesel with other fuels can be seen in Table 1.

Table 1. Comparison of Energy Yield from One Btu of Fossil Energy Used

| Fuel | * Energy Yield | Net Energy (loss) or gain |
|-----------|----------------|---------------------------|
| Gasoline | 0.74 | (26 percent) |
| Diesel | 0.83 | (17 percent) |
| Ethanol | 1.34 | 34 percent |
| Biodiesel | 3.20 | 220 percent |

*Yield in liquid fuel Btus per Btu of fossil fuel energy dedicated.

Source: USDA, Economic Research Service Report number 721, "Estimating The Net Energy Balance Of Corn Ethanol", July 1995

At current market prices B20 costs an average 15 cents more per gallon than conventional diesel, but the price gap is shrinking. The alternative fuel can be used with existing engine technology and fueling infrastructure, requiring little to no modification before use. This means that there are significant environmental and energy benefits at minimum increases in cost.

Why is the Laboratory interested in Biodiesel?

National Leadership

With the U.S. headed towards increased strains on energy supplies, finding alternative sources can help protect national energy security. In a speech following his appointment as U.S. Secretary of Energy, Spencer Abraham remarked that the President supports a strategy to “enhance our commitment to conservation and energy efficiency... and encourage investment in new technology to further the development of renewable energy sources.” Today, the U.S. imports 54 percent of its oil from abroad. Each year, the Laboratory uses over 165,000 gallons of diesel fuel in everything from passenger vehicles, to heavy equipment, to smaller laboratory equipment. Using domestic agricultural products for Laboratory fuel requirements reduces the dependence on foreign oil. By switching to a product developed from bioenergy technology, the Laboratory will join the Department of Defense and the U.S. Forest Service in ensuring national energy security and supporting American agriculture.

For the past decade, the Federal Government has been working hard to lead by example in reducing the nation’s environmental impact. Five Executive Orders (13101, 13123, 13134, 13148, 13149) were signed for the purpose of “greening the government.” These orders focus on promoting biobased products, such as biodiesel, in order to improve the quality of our natural resources. Executive Order 13134, which deals primarily with promoting biobased products and bioenergy, states:

“Current biobased product and bioenergy technology has the potential to make renewable farm and forestry resources major sources of affordable electricity, fuel, chemicals, pharmaceuticals, and other materials. These technologies... have the potential to reduce our Nation's dependence on foreign oil, improve air quality, water quality, and flood control, decrease erosion, and help minimize net production of

greenhouse gases. It is the policy of this Administration, therefore, to develop a comprehensive national strategy, including research, development, and private sector incentives, to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in large national and international markets.”

The Laboratory can do its part in accomplishing this initiative by using a biobased product such as biodiesel.

Pollution Prevention and Energy Efficiency Leadership Goals

While furthering national initiatives, the use of biodiesel can also aid the Laboratory in accomplishing institutional goals. One measure of our commitment to protecting the environment is the Laboratory’s achievement of the DOE pollution prevention and energy efficiency leadership goals. The first fuel related goal is to reduce the Laboratory fleet’s entire annual petroleum consumption by at least 20 percent by 2005. A second goal is to have 75 percent of all fuel be alternative by 2005 and 90 percent by 2010. The third goal is to acquire each year at least 75 percent of light-duty vehicles as alternative fuel vehicles.

By using a 20 percent blend of biodiesel in laboratory machinery and vehicles, all three of these goals can be accomplished simultaneously. This means that any cost increase from using biodiesel would be less than the cost increase from achieving these goals in other ways. Mixing biodiesel with petroleum will lessen the amount of petroleum consumed yearly, accomplishing the first goal. With biodiesel in place Laboratory-wide, all vehicles using a blend of at least 20 percent biodiesel can be considered alternative fuel vehicles. This accomplishes both the second and third goals, without the added cost of purchasing new vehicles or modifying the current ones.

Health and Environmental Benefits

The National Biodiesel Board and the Lovelace Respiratory Research Institute have studied the pollutants produced from biodiesel combustion. Their research details the emissions levels of several potentially harmful contaminants and their health effects. One hundred percent biodiesel (B100) has no pronounced toxicity or mortality-causing effects, no neurotoxins, and no fertility or reproductive effects. This is a great benefit over petroleum-based diesel, which is suspected of causing all of these health problems. With biodiesel, there is a 30 percent reduction in particulate matter. High levels of particulate matter, sometimes produced from diesel exhaust, are associated with lung and eye irritations. B100 shows a 50 percent reduction in the release of carbon monoxide (CO). CO is a gas that can cause dizziness, nausea, or even death at higher concentrations. With B100, ozone emissions are 50 percent less than those of diesel fuel. Ozone emission exposure can have similar effects to CO. Higher than normal concentrations of ozone can cause headaches, decreased pulse rate and blood pressure, and irritation of the eye and respiratory system. Emissions of hydrocarbons from pure biodiesel are 95 percent lower than diesel fuel. Hydrocarbons contribute to the formation of smog and ozone. Another health benefit to biodiesel is that it produces zero sulfur emissions. These emissions can be associated with heart and lung disorders, as well as acid rain. A final advantage to using biodiesel is that it contains little to no aromatic compounds. These compounds, found in petroleum diesel, are known cancer-causing agents for animals and possibly for humans. Compared to standard diesel fuels, the use of biodiesel will improve the health and environment of Laboratory staff. A

summary of the health and environmental benefits from emissions reduction can be seen in Table 2.

Table 2. Summary of Emissions Reductions for B100 and B20 (as compared to petroleum diesel fuel)

| Emissions | Health/Environmental Effects | % Reduction for B100 | % Reduction for B20 |
|--------------------|--|----------------------|---------------------|
| Particulate Matter | Lung/Eye Irritations | 30 | 22 |
| Carbon Monoxide | Dizziness, Nausea, Death | 50 | 20 |
| Ozone | Headaches, Eye/Nose/ Lung Irritations | 50 | 10 |
| Hydrocarbons | Formation of Smog/Ozone | 95 | 30 |
| Sulfur Dioxide | Heart/Lung Disorders, Acid Rain | 100 | 20 |
| Aromatic Compounds | Carcinogens | 90 | 13 |

Biodiesel Users Around the Country

Although biodiesel is still relatively new, there are organizations across the country that have experience using B20 and B100 in similar environments and equipment as the Laboratory, and with great success. From Minnesota to Florida, San Diego to Connecticut, diesel users are discovering the benefits of biodiesel. One organization leading the way to using alternative fuels is Yellowstone National Park. The park is now using 100 percent rapeseed (canola) oil as a biodiesel fuel in a park pickup truck. Since 1995, Yellowstone employees have driven more than 130,000 miles on 100 percent biodiesel fuel. At first, there were concerns over whether bears would be attracted to the sweet smell of the fuel. Park rangers feared animals chasing after the truck in the hopes of catching some french fries. However, this proved to be unfounded; the bears didn't notice the difference. The use of biodiesel in the truck was so successful that the project has been expanded to include tour buses, garbage trucks, and some heavy equipment. Plans are underway to use biodiesel in all 300 of the park's diesel powered vehicles by the spring of 2002.

Other satisfied users of biodiesel include the National Aeronautics & Space Administration, the Department of Defense (Ft. McCoy, Wisconsin), several Department of the Interior sites (Washington, D.C.), Scott Air Force Base (Illinois), Camp Lejeune Marine Corps Base (North Carolina), Miramar Marine Corps Air Station (San Diego), New York City US Postal Service, USDA Forest Service (Wyoming), National Park Service, New Jersey Transit, Connecticut Department of Transportation, New Jersey Department of Transportation, Missouri Department of Transportation, Five Seasons Transportation (Cedar Rapids, Iowa), Bi-State Development Agency (a mass transit provider in St. Louis, Missouri), Florida Power and Light, Georgia Power, Duke Energy Corporation (Charlotte, NC), Pacific Waste Services (San Diego, CA), and the City of Tacoma, Washington. The Department of Defense plans to implement the use of four million gallons of B20 by the end of the year.

Implementation of Biodiesel at the Laboratory

Through the combined efforts of Johnson Controls Northern New Mexico (JCNNM) and the Environmental Stewardship Office (ESO), the use of biodiesel in Laboratory equipment may soon become a reality. The idea was planted in August of 2000 and over the past two years has moved from a conceptual phase to an investigation phase. Jim Stanton, Pollution Prevention coordinator at JCNNM, states, "Momentum is building for the switch to alternative fuels. We are proceeding cautiously and finding solutions to potential problems before the changeover. We're prepared to meet this head on."

Pilot Program to Evaluate Potential Concerns

Although biodiesel clearly outweighs petroleum diesel in terms of health and environmental benefits, and accomplishes both national and institutional mandates, there are some concerns associated with its implementation. Currently, an aggressive investigation is underway to address these issues. The Laboratory plans to design a pilot program to evaluate the performance of biodiesel and carefully monitor some of the present concerns over its use. This pilot program would be designed to assess whether it is safe and practical to implement biodiesel in all Laboratory machinery. Some of the key quality control focuses of the test program are these: the performance of the alternative fuel under conditions of cold temperatures and long storage; the frequency necessary for changing filters with the initial use of the fuel; and the potential for the fuel to be affected by the addition of water due to condensation in the tank. Implementation will begin with a blend of 20 percent biodiesel and 80 percent diesel. This will be done in order to proceed in increments and to address any concerns that are raised along the way. A technical article will be written on the Laboratory's experience with biodiesel in order to provide documentation for other government agencies and private organizations.

John Keene, Superintendent of Heavy Equipment for JCNNM, is the lead technical consultant for this project. He reported, "There have been some big hurdles along the way, but we're making every effort to ensure a smooth transition when we decide to start using biodiesel. With the high quality of our maintenance people, and the technical expertise here at the Lab, we feel confident about moving forward."

Supply and Maintenance

Supply and maintenance are two related topics of concern for the investigation team. Discussions are underway for an arrangement with a local commercial distributor. This will help cut shipping costs, keeping added fuel costs down. In dealing with a local distributor, it is also easier to regulate the maintenance of the fuel supply. Like petroleum diesel, biodiesel must be stored at the proper temperature and should be routinely inspected for water content. This maintenance will help make certain that the use of biodiesel will not void any equipment warranties.

Warranty Concerns

Manufacturers are currently evaluating the use of biodiesel in their machinery. In December 2001, John Deere approved the use of B20 in all of its diesel-powered products. Ted Breidenbach, Manager of Worldwide Engine Engineering for John Deere Power Systems, said, "Biodiesel is a valuable tool for helping reduce engine emissions. It also stands as one of the

linchpins in the movement to develop alternative uses for commodity products that can ultimately deliver more value to our producer customers... We're confident that when it's used per factory specifications it will generate the performance producers have come to expect from their John Deere equipment."

Cold Weather Operations

Maintaining the proper temperature of the alternative fuel is extremely important. In its pure form, the fuel must be stored above 37 degrees Fahrenheit, or it has to be reheated above 80 degrees Fahrenheit before it will reliquify. Blending biodiesel with petroleum diesel can lower this storage temperature significantly. Tests are being conducted to make sure that the fuel will function properly in New Mexico temperatures, even when stored for long periods of time. While this is a serious concern, there is extensive evidence that biodiesel can hold up under all weather conditions. Five Seasons Transportation used B20 in Cedar Rapids, Iowa. This company used the fuel for over 1.4 million miles of operation in their bus fleet during one of the coldest winters on record, with temperatures reaching below -20 °F for almost a week. Roger Hagum, a representative from Five Seasons Transportation, said, "We had no problems using biodiesel in freezing weather. If we hadn't told our mechanics we were using B20, they never would have known the difference." Biodiesel was also used in two buses by the Department of Defense in Ft. McCoy, Wisconsin, in freezing temperatures. Terry Nolan, of the Department of Logistics, reported:

"All buses had been parked outside. The weekend temperatures averaged below zero with above average winds. The temperature the morning of the 27th [of December] was approximately -3°F... The two Soy/Diesel buses started up without any problems. Two of the eight regular Diesel powered buses would not start and had to be serviced."

Increased Lubricity

Some other technical difficulties are also being worked out. Biodiesel has a high lubricity, meaning that it acts as a very strong solvent. When used in machinery formerly run with diesel fuel, this solvent will flush out all old fuel deposits from the equipment. Initially, use of biodiesel will require frequently changing the filters. The investigation will determine the proper actions to be taken so that filters and machinery will not clog from too high a solvency content. Biodiesel users from the Bi-State Development Agency, a mass transit provider for the St. Louis area in Missouri, experienced similar concerns. They suggested that, in older tanks, it might be helpful to first clean the tank before filling it with biodiesel. In newer tanks with less build up, this was not necessary. Bi-State Development Agency reported that once the tanks were cleaned out by biodiesel, the high lubricity of B20 increased injector life and decreased the need to maintain their vehicles. Other users also reported this benefit. While there might have been an initial investment in changing the filters, once the biodiesel cleaned out old diesel deposits the engines ran cleaner and with less long-term maintenance costs.

Conclusions

The Los Alamos National Laboratory is committed to pursuing innovations in science and technology to make the world a better and safer place. Inherent in this vision is the responsibility to consistently strive to improve our work environment and the natural environment in which we

live. Using biodiesel can help us achieve these goals. The change to alternative fuels will improve the quality of life by reducing air emissions at the Laboratory, supporting regional and national agriculture markets, and ensuring domestic fuel supplies for future security. It will help meet environmental standards, both those mandated by Federal Government and by the DOE. And finally, it will contribute greatly to the national effort to educate the country on environmental conservation and protection issues. No other potential action will allow us to achieve such a broad victory, with so little time and money invested. This success will not come easily; it will take hard work and determination to overcome obstacles. In the words of Eleanor Chapman, the Green Acquisition Advocate for ESO, "We are dedicated to exploring the potential of this new technology. We are excited about the possibilities and look forward to its implementation."